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Evaluation on the Use of Plants and Equipment in Building Project Delivery in Imo State, Nigeria

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Modern construction is characterized with complex designs, new and innovative materials that are sensitive with high precision. In addressing the accompanying challenges, mechanization of construction process is said to be the guarantee especially in this era of crash programmes and advancement in technology to reduce poor workmanship and eliminate avoidable holdup in construction processes in the industry. Amidst this belief, attributes of construction industry in Imo state still reflect ineffectiveness in the use of plant and equipment. Hence, the study assesses the involvement of plants and equipment in building delivery for improved project performance. Field survey and work measurement methods were adopted to gather both non-parametric and parametric data respectively. The survey design targeted the sampled building professionals while work measurement focused on selected earth and concrete works in the area of the study. Inferential and descriptive statistical tools of Chi-square on likert scale and Comparative measurements on work activities respectively were used to analyze the respective non-parametric and parametric data. Findings show that selection of various plants are dependent on their rates of use for increased site work productivity; while the socio-economic and political issues as militating factors against effective use of plants are determined by their levels of acceptance. It was also discovered comparatively that mechanization of construction processes is more time and cost effective in building project than manual approach at work. The study therefore recommends that a systematic and holistic awareness be created by the stakeholders on the usefulness of mechanization of construction process in physical development. Besides, government should

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enforce construction methodology plan as a mandatory document for approval of any building plans; while frantic effort should be targeted at reviving the abandoned steel manufacturing industry at Ajeokuta, Ogun state to revolutionize the construction methodology of construction industry in Nigeria.

Keywords: Plants and equipment; construction methods; construction process; site work productivity; time and cost effectiveness.

1. INTRODUCTION

The implication of manual production process on building delivery performance have sparked growing concern for adequate plant input in construction process, especially in heavy construction projects. Although the dependency on manual production approach in the medieval era was due to low level of science and technology, complexity in design and advancement in construction elements require mechanization of construction process for effective delivery of projects in Nigeria. According to [1] construction is the final objective or transformation of a design through production activities into a useful by man/machines. Man and machine during construction process transform project plans into realities; and as the construction tasks become complex and demanding machines evolve.

Plants and equipment (machine) is indispensable item of construction resources these days. It produces output at an accelerated speed, and enables completion of construction tasks in a limited time [2]. This is because plants saves time and manpower, increase productivity of and improves quality of works. In a broader sense therefore, mechanization can be seen as a method of construction situation where the use of plants and equipment are employed in the majority of the activities [3].

In many developed nations, use of plants and equipment have revolutionized majority of the operations that were manually based earlier. Some have even attained between 30 -50% partial mechanization in some areas of construction [4]. In Nigeria, this is not the situation; because not much has been achieved in the use of construction plants and equipments. Ranges of socio-economical, political, and historical factors are known to have hinders progress in effective use of plants and equipment for improved construction project performance in Nigeria in general. Among the factors are believed to be high cost of acquiring plants and equipment from the foreign countries, since there is no functional iron and steel industry in Nigeria. In the list also is the unavailability of spare parts of the plants, which usually affects adversely the schedules of project work programme [5]. Although there is no clear evidence on the extent of use of plants in the study area, from the foregoing, it is obvious that ineffective use of construction plants, poor production performance, and the attendant waste of scarce resources have continued to mount pressure on project delivery in Nigeria. Considering the level of construction activities in the major cities of Imo state with the absence of plants/equipment parks, the availability and affordability of required construction plants in achieving effective mechanization of construction process in the industry is seemingly not feasible. Since every construction project has its own peculiar characteristics, selection and deployment of appropriate categories of construction plants remains a vital issue for effective project delivery [6]. According to [7] categorization of plants and equipment into their functional uses ranks high amongst other objectives in deployment of plants.

In the context of the study, it is therefore necessary to investigate the use of plants/equipment, examine the factors affecting the effectiveness of use of plants, and to examine the implication of adoption of mechanization and manual methods of construction in the study area.

2. RESEARCH METHODS AND PROCEDURE

A survey research design method was adopted in soliciting for information from the targeted respondents in the area of the study. The data obtained are of discrete nature for deductive reasoning to arrive at solutions to the problem of the study. Structured questionnaires and activities sampling methods were devised for gathering data in the field. The targeted professionals in the building industry include; the Architects, Builders, Civil engineers and Quantity surveyors in the study area for data on the usage

rate of the various categories of the plants/equipment and the implication of the major socio-economic and political issues on the effective use plants/equipment for improved project delivery in the area. Assessment of effects of mechanization and manual methods of work production respectively was by direct observation of construction activities through method study and work measurements.

Random method of sampling was adopted in gathering data from the field; using system approach in the survey design. The instrument of data collection used was administered and retrieved directly.

Data obtained from the survey were analyzed using non parametric tools like likert scale for ranking, and Chi-square for test of independency between the independent and dependent factors. Besides, performances of the mechanical and manual methods of production were evaluated.

In the study, the respective methods of data analyses according to [8] are therefore presented in the following forms. They are:

$$\text{Likert Scale} = \text{MS} = \sum_{i=1}^{5} \frac{(FxS)}{N} = \frac{5f1+4f2+3f3+2f2+f1}{f5+f4+f3+f2+f1} = = Eq.1$$

Where;

MS is Mean Score,
F = Frequency of Sample,
S = Weighted Score,
N = Total Sample Number.

Thus the Ranking Index (RI) is expressed as;

$$\text{RI} = \sum_{i=1}^{5} \frac{(FxS)}{5N} = = = Equ.2$$

Chi-square (X^2) = $\Sigma^{k}_{i=1}\ \Sigma^{k}_{i=1}((O_{ij} - E_{ij})^2 / E_{ij})$ (for test of independence) = $Equ.3$

Where;

X^2 is the Chi-square,
O = Observed Frequency in the Sample,
E = Expected Frequency if H_o is true,
K = the number of category of variables.

In construction of contingency table in the test, the expected frequency (E) therefore is presented in the form:

$$E_{ij} = (R_i \times C_j) / N = = = Equ.4$$

Thus, if $X^2_{1-\alpha(r-1)(c-1)}$ calculated is more than the critical value at 95% confidence interval, the H_o is failed to be accepted, otherwise it is accepted and, the H_a rejected, to confirm the independency or otherwise of one group of variables on the others in the study area.

3. DATA PRESENTATION, ANALYSES AND DISCUSSIONS

In assessment of the acceptance level of application of the various categories of construction plants and equipment for improved work productivity, Table 1 shows that Scraper equipment, Haulage, and Dozer's equipment rank first, second and third places with the corresponding mean scores of 4.10, 4.02, and 3.76 respectively. Hoisting equipment however takes the last place amongst the identified categories of construction plants and equipment with the mean score of 2.23 in the study area.

Table 2 shows that among the ten factors identified in the study, High maintenance cost of machine, High procurement cost of the machines, and Scarcity of spare parts have the leading roles of first, second and third positions with the corresponding mean scores of 4.52, 4.49, and 4.35 respectively, as factors affecting the effectiveness of use of plants and equipment. Lack of indigenous plant manufacturing industry in Nigeria for heavy projects with mean score of 2.28 comes last in ranking.

In Table 3 are shown the cost implications of both mechanical and manual methods of production. In all the earth and concrete works activities, use of plants and equipment are seen to cost lesser than the manual approach of production in the study area. On average, the total cost of completing the measured work activities using plants and equipment is higher than the cost incurred on the same set of activities using manual labour with about 5%.

The percentage values obtained for the cost impact of mechanization on the earth and concrete works however are presented in Table 4, with a view to emphasizing the level at which the cost differences exist.

Table 1. Acceptance level of application of the various categories of construction plants and equipment in the study area

S/N	Categories of Plants/Equipment	(5)	(4)	(3)	(2)	(1)	Total	MS	Rank	Index
1	DOZER	137	102	28	54	28	**349**	3.76	3rd	0.75
2	SCRAPER	100	200	40	5	4	**349**	4.10	1st	0.82
3	LOADER	150	100	0	50	49	**349**	3.72	4th	0.74
4	EXCAVATOR	46	41	39	163	60	**349**	2.56	7th	0.51
5	HAULAGE	100	200	17	20	12	**349**	4.02	2nd	0.80
6	COMPACTOR	76	56	28	157	32	**349**	3.02	5th	0.60
7	CONCRETE PLANT	63	50	28	165	43	**349**	2.78	6th	0.56
8	MATERIAL HANDLING PLANTS	39	47	28	139	96	**349**	2.26	8th	0.45
9	HOISTING EQUIPMENT	18	40	43	153	95	**349**	2.23	9th	0.45

Source: Author's Field Survey Data, (2021)

Table 2. Severity levels of effects of socio-economic and political factors on the effectiveness of use of construction plants and equipment

S/N	Factors Affecting the Effective Use of Construction Plants/Equipment	(5)	(4)	(3)	(2)	(1)	Total	MS	Rank	Index
1	High Cost of Plants and Equipment	220	100	10	19	0	349	4.493	2nd	0.90
2	High Maintenance Cost of Machines	250	70	0	20	9	349	4.524	1st	0.90
3	Scarcity of Machine Spare Parts	230	50	50	0	19	349	4.352	3rd	0.87
4	Implication of Government Policy	189	80	40	20	20	349	4.037	6th	0.81
5	Lack of Indigenous Manufacturing Industry	200	77	0	70	2	349	2.281	10th	0.46
6	Foreign Firm Domination in the Industry	15	10	50	260	14	349	2.829	9th	0.57
7	Lack of Qualified Expertise	180	140	0	29	0	349	4.350	4th	0.87
8	Insufficient Number of Available Plants/Equipment	222	70	30	0	27	349	4.318	5th	0.86
9	Lack of New Technology and Methods	210	14	14	100	11	349	3.885	7th	0.78
10	Challenges in Allocation of Plants and Equipment	117	70	0	120	42	349	3.264	8th	0.65

Source: Author's Field Survey Data, (2021)

Table 3. Comparative assessment of cost of using plants and manual labour in Earth and concrete works in a building project

Construction Task	Cost Analyses of Production Methods							
	MANUAL LABOUR				PLANTS/EQUIPMENT			
	Activity	Mode	Time	Cost	Activity	Mode	Time	Cost
Top Soil Excavation Works	Labour Wage (840m^3)	Direct Labour	16hrs	214,000	Site Clearing (840m^3)	Wheel-dozer + Skimmer	16hrs	170,000
					Labour Wages	-		20,000
					Fueling and Lubrication	-		12,000
	Total cost			**214,000**	**Total Cost**			**202,000**
Pit Excavation	Trenching (362m^3)	Direct Labour	16hrs	140,000	Trenching (362m^3)	Crawler Back-actor Hoe	12hrs	100,000
					Labour Wages	-		12,000
					Fueling and Lubrication			8,000
	Total Cost			**144,000**	**Total Cost**			**120,000**
Backfill and Compaction	Earth Filling and Compaction (164m^3)	Direct Labour	16hrs	116,500	Earth Filling and Compaction (164m^3	Angle Dozer	8hrs	90,000
					Labour Wages	-		12,000
					Fueling and Lubrication	-		6,500
	Total Cost			**116,500**	**Total Cost**			**108,500**
Concrete works	Casting at Ground Floor Level (86.4m^3)	Direct Labour	8hrs	140,000	Casting at Ground Floor Level (86.4m^3)	Tilting Drum Mixer & Mixing Bucket	6hrs	90,000
						Labour Wages		15,000
						Fueling and lubrication		8,000
	Total Cost			**140,000**		**Total Cost**		**113,000**
	Casting at 3m Height (54m^3)	Direct Labour	8hrs	168,500	Casting at 3m Height (54m^3)	Tilting Drum Mixer, Mobile Crane & Mixing Bucket	8hrs	140,000
						Labour Wages		16,000
						Fueling and lubrication		10,000
	Total Cost			**168,500**	**Total Cost**			**166,000**

Source: Author's Work Measurements and Cost Analyses, (2021)

Table 4. Cost benefit on effective use of construction plants and equipment in the industry

S/N	Construction Task	Work Activity	Cost of Manual Method (#)	Cost of Mechanical Method (#)	Cost Difference (#)	Average Cost Effectiveness of Plants (%)
1	Earth Works	Surface Excavation	214,000	202,000	12,000	2.88
		Trench Excavation	144,000	120,000	24,000	9.09
		Backfilling & Compaction	116,500	108,500	8,000	3.56
2	Concrete Works	Ground Floor Slabs	140,000	113,000	27,000	10.67
		Reinforced Concrete Columns	168,500	166,000	2,500	0.75
	Total		**783,000**	**709,500**		

Source: Author's Work Measurements and Cost Analyses, (2021)

Table 5. X^2 Contingency table for test of independency of acceptance levels of usage of various categories of plants for site work productivity

S/N	Economic Factors causing fluctuation in Building Material Prices	Weight of Acceptance	Observed Frequency (O)	Expected Frequency (E)	O-E	$(O-E)^2$	$(O-E)^2/E$
1	**DOZER**	5	137	81	56	3136	38.7
		4	102	93	9	81	0.87
		3	28	28	0	0	0
		2	54	101	47	2209	21.9
		1	28	47	19	361	7.7
2	**SCRAPER**	5	100	81	19	361	4.5
		4	200	93	107	11449	123.1
		3	40	28	12	144	5.1
		2	5	101	96	9216	91.2
		1	4	47	43	1849	39.3
3	**LOADER**	5	150	81	69	4761	58.8
		4	100	93	7	49	0.53
		3	0	28	28	784	28
		2	50	101	51	2601	25.8
		1	49	47	2	4	0.09
4	**EXCAVATOR**	5	46	81	35	1225	15.1
		4	41	93	52	2704	29.1
		3	39	28	11	121	4.3
		2	163	101	62	3844	38.1
		1	60	47	13	169	3.6
5	**HAULAGE**	5	100	81	10	361	4.5
		4	200	93	167	11449	123.1
		3	17	28	11	121	4.3
		2	20	101	81	6561	65
		1	12	47	35	1225	26.1
6	**COMPACTOR**	5	76	81	5	25	0.31
		4	56	93	38	1444	15.5
		3	28	28	0	0	0
		2	157	101	56	3136	31
		1	32	47	15	225	4.8

S/N	Economic Factors	Weight of	Observed	Expected	O-E	$(O-E)^2$	$(O-E)^2/E$
7	**CONCRETE**	5	63	81	18	324	4
	PLANTS	4	50	93	43	1849	19.9
		3	28	28	0	0	0
		2	165	101	64	4096	40
		1	28	47	4	16	0.34
8	**MATERIALS**	5	39	81	42	1764	21.8
	HANDLING	4	47	93	46	2116	22.8
	PLANTS	3	28	28	0	0	0
		2	139	101	38	1444	14.3
		1	96	47	49	2401	51.1
9	**HOISTING**	**5**	**18**	81	63	3969	49
	EQUIPMENT	**4**	**40**	93	53	2809	30.2
		3	**43**	28	15	225	8,04
		2	**153**	101	52	2704	26.8
		1	**93**	47	48	2304	49.0
	TOTAL X^2 (CALCULATED)						**1147.68**

Source: Analyses of Data from the Field, (2021)

Table 6. X^2 contingency table for test of independent of acceptance level on the effect of socio-economic and political factors on effective use of plant and equipment

S/N	Socio-economic and Political Factors	Weight of Impact	Observed Frequency (O)	Expected Frequency (E)	O-E	$(O-E)^2$	$(O-E)^2/E$
1	High Cost of Plants and Equipment	5	220	183	37	1369	7.5
		4	100	68	32	1024	15.1
		3	10	19	9	81	4.3
		2	19	64	45	2025	31.6
		1	0	14	14	196	14
2	High Maintenance Cost of Machines	5	250	183	67	4489	24.5
		4	70	68	2	4	0.06
		3	0	19	19	361	19
		2	20	64	44	1936	30.3
		1	9	14	5	25	1.8
3	Scarcity of Machine Spare Parts	5	230	183	47	2209	12.1
		4	50	68	18	324	4.8
		3	50	19	31	961	50.6
		2	0	64	64	4096	64
		1	19	14	5	25	1.8
4	Implication of Government Policy	5	189	183	6	189	0.2
		4	80	68	12	144	2.1
		3	40	19	21	441	23.2
		2	20	64	44	1936	30.3
		1	20	14	6	36	2.6
5	Lack of Indigenous Manufacturing Industry	5	200	183	17	289	1.6
		4	77	68	9	81	1.2
		3	0	19	19	361	19
		2	70	64	6	36	0.56
		1	0	14	12	144	10.3
6	Foreign Firm Domination in the Industry	5	15	183	168	28224	154.2
		4	10	68	58	3364	49.5
		3	50	19	31	961	50.6
		2	260	64	196	38416	600.3
		1	14	14	0	0	0

S/N	Socio-economic and	Weight	Observed	Expected	O-E	$(O-E)^2$	(O-
7	Lack of Qualified Expertise	5	180	183	3	9	0.05
		4	140	68	72	5184	76.2
		3	0	19	19	361	19
		2	29	64	35	1225	19.1
		1	0	14	14	196	14
8	Insufficient Number of Available Plants/Equipment	5	222	183	39	1521	8.3
		4	70	68	2	4	0.06
		3	30	19	11	121	6.4
		2	0	64	64	4096	64
		1	27	14	13	169	12.1
9	Lack of New Technology and Methods.	5	**210**	183	**27**	**729**	**4.0**
		4	**14**	68	**54**	**2916**	**42.9**
		3	**14**	19	**5**	**25**	**1.3**
		2	**100**	64	**36**	**1296**	**20.3**
		1	**11**	14	**3**	**9**	**0.64**
10	Challenges in Allocation of Plants and Equipment	**5**	**117**	183	**66**	**4356**	**23.8**
		4	**70**	68	**2**	**4**	**0.06**
		3	**0**	19	**19**	**361**	**19**
		2	**120**	64	**56**	**3136**	**49**
		1	**42**	14	**28**	**784**	**56**
	Total X^2 (Calculated)						**1663.33**

Source: Analyses of Data from the Field, (2021)

As seen in Table 5, Row (r) is 9, while Column (c) = 5; with Confidence Interval of 90%. Consequently, X^2_{cal} is 114.68; while $X^2_{1-\alpha(r-1)(c-1)}$ from the table is 46.20.

Hence, since X^2 calculated is greater than the critical X^2 tabulated, we fail to accept H_o, but reject it. H_a therefore is accepted, that categories of plants and equipment are dependent on their rates of usage in their effects on productivity of work in the study area.

The rate of use of the various categories of plants and equipment which according to the findings affects productivity of the construction works as a matter of fact remains a critical issue in the industry. The pace, complexity and cost of modern construction are not compatible with the traditional approach in construction processes; hence the need for mechanization of construction process.

In line with [1], the finding implies that appropriate mechanization of construction tasks usually increase job site productivity.

In Table 6, Row (r) is 10, while Column (c) = 5; with Confidence Interval of 90%. Thus, X^2_{cal} is 1663.33; while $X^2_{1-\alpha(r-1)(c-1)}$ from the table is 51.00.

Hence, since X^2 calculated is greater than the critical X^2 tabulated, we fail to accept H_o, but reject it. H_a therefore is accepted, that the socio-economic and political factors are dependent on their level of acceptance in affecting the effective use of plants and equipment.

The socio-economic and political factors according to the findings contribute considerably to effective use of machine for improved project delivery in the study area. According to [1], it is very necessary to understand the criteria for appropriate selection towards effective use of machines before deployment to site; in order to achieve optimal use of plants and equipment in a given construction task. The finding therefore justifies his conclusion that equipment selection is highly influenced by many factors like; historical data, socio-economic, political factors and experience from similar projects, for effective delivery of projects.

4. SUMMARY OF FINDINGS

In this study, inference for every specific objective was realized respectively in the context of the work. In the assessment of level of application of the various categories of construction plants and equipment, Scraper equipment, Haulage, and Dozer's equipment are discovered as the most commonly used plants and equipment for improved work productivity in the study area. Analysis explains that the choice of the various categories of plants and equipment

are dependent on their rates of usage for their impact on productivity of work in the study area.

On the effective use of the various construction plants and equipment, high maintenance cost of machine, high procurement cost of the machines, and scarcity of spare parts are seen as the major causes of low level of use of construction plants. It is therefore deduced that the socio-economic and political factors militating against mechanization of construction processes are dependent on their level of acceptance for leading to the ineffective use of plants and equipment in the study area.

Measured information on the cost implications of mechanical and manual methods of production respectively emphasis the fact that use of plants and equipment is cost effective than manual approach, as well save time; even at the short run when there is effective construction methodology and plan.

5. RECOMMENDATIONS

Since the low mean scores of most of the available plants and equipment implies low usage rate in construction, adequate awareness by the building professionals in the Nigeria construction industries on the significance of mechanization of construction process over manual approach should be encouraged for a revolutionalised construction methodology in Nigeria.

In the light of the finding that high cost of maintenance, high cost of procurement, and scarcity of spare parts of the machines mostly affect adversely the effective use of plants for improved project delivery, Nigeria government as a matter of urgency should make a frantic effort to review and revive the popular Ajeokuta steel industry project abandoned decades of years ago.

It is also recommended that every project be critically examined of its scope and nature before embarking on either fully or partially mechanized construction process, so as to ensure effectiveness in project time and cost deliveries. In order to guarantee this condition, government is hereby advised to incorporate and enforce construction methodology plan as an official production document in the general condition of physical development before the approval of such project by the authority.

6. CONCLUSION

In conclusion, the need to effectively sensitize all the stakeholders and revolutionalise the construction process in Nigeria from manpower production arrangement to the mechanization is of essence and timely in project delivery, as project cost and time will be reduced with optimum performance. Hence, more plants will be used frequently in the study area for increased site work productivity.

With the revival of the abandoned steel manufacturing industry and possibly more new one, costs of procurement, maintenance, and scarcity of machine's spare parts will be significantly reduced to a barest minimum to encourage mechanization in the industry. This scenario automatically will encourage indigenous firms in the competition against the dependency on the foreign nations for both the plants/equipment and prospective construction firms.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the authors.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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